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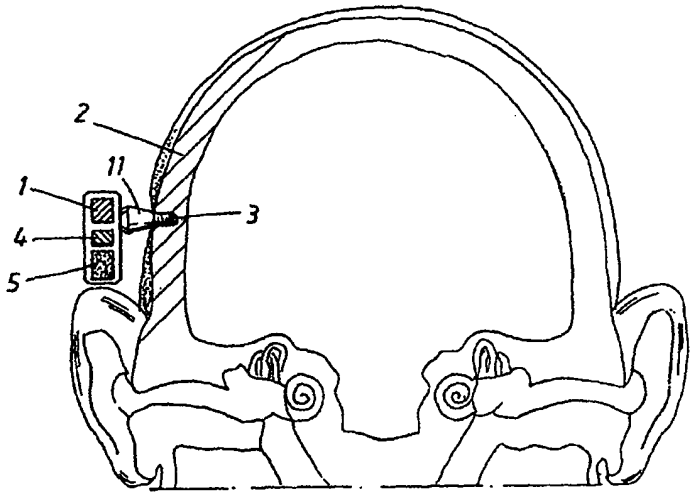
For two-letter codes and other abbreviations, refer to the "Guidance Notes on Codes and Abbreviations" appearing at the beginning of each regular issue of the PCT Gazette.

(54) Title: HEARING AID APPARATUS



(57) Abstract: The invention relates to a hearing aid apparatus of the type which is intended for sound transmission from one side of the head to the cochlea on the other side of the head for rehabilitation of patients with unilateral hearing loss, i.e. individuals with normal or a slightly impaired hearing on one ear and a profound hearing loss in the inner ear on the other side of the head. The hearing aid apparatus is based on the bone conducting principle for bone anchored hearing aids and comprises a vibrotary generating part which is mechanically anchored by means of osseointegration in the skull bone (2) at the deaf side of the patient and arranged to transmit vibrations through the skull bone from the deaf side to the inner ear on the other side of the patient. The frequency characteristics of the apparatus is preferably adapted in such a way that the amplification is higher for frequencies above 1 kHz than for lower frequencies which is in contrast to an ordinary bone anchored hearing aid.

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Hearing aid apparatus

The present invention relates to a hearing aid apparatus of the type which is intended for sound transmission from one side of the head to the cochlea on the other side of the head for rehabilitation of patients with unilateral hearing loss, i e individuals with a normal or a slightly impaired hearing on one ear and a profound hearing loss in the inner ear on the other side of the head.

For the rehabilitation of these patients with single sided deafness traditional CROS (Contralateral Routing Of Signal) hearing aids are used today. Such a hearing aid comprises a microphone on the deaf side of the patient and an amplifier with a loudspeaker on the good ear. The sound is then transmitted from the deaf side to the good ear to avoid the head shadow effect which otherwise makes it difficult for a patient to hear anything from the deaf side of the head. One example of this type of hearing aid is described in US Patent No. 3,809,829.

Another example of a previously known CROS device comprises a powerful traditional hearing aid placed on the deaf ear. In this case the sound is amplified by the apparatus and picked up in the ear canal and converted into vibrations in the skull bone. The vibrations are then transmitted to the cochlea of the good ear. This type of apparatus is usually named transcranial CROS.

Unfortunately these types of hearing aids for rehabilitation of patients with single sided deafness have significant drawbacks. In the first-mentioned apparatus the hearing in the good ear is reduced, due to the apparatus itself in the ear but also due to the fact that the signal must be transmitted from the microphone on the deaf side to the other side by means of a cable or for instance by means of a FM radio link. A transcranial CROS, on the other side, involves acoustic feed-back problems unless the

ear plug is made very tight. Another disadvantage with transcranial CROS devices is the fact that the sound quality is poor in these devices as they often has to be working with full power.

For persons with other types of impaired hearing, for instance a misfunction in the auditory canal or a chronic ear inflammation, there are bone conducting hearing aids on the market today, i e bone anchored hearing aids which mechanically transmit the sound information to a persons inner ear via the skull bone. Such a hearing aid is described for instance in US Patent No. 4,498,461.

In such a bone anchored hearing aid the sound information is mechanically transmitted by means of a vibrator via the skull bone to the inner ear of a patient. The hearing aid device is connected to an implanted titanium screw installed in the bone behind the poor, external ear and the sound is transmitted via the skull bone to the cochlea (inner ear) of this poor ear, i e the hearing aid works irrespective of a disease in the middle ear or not. The bone anchoring principle means that the skin is penetrated which makes the vibratory transmission very efficient.

This type of hearing aid device has been a revolution for the rehabilitation of patients with certain other types of impaired hearing. It is very convenient for the patient and almost invisible with normal hair styles. It can easily be connected to the implanted titanium fixture by means of a bayonet coupling or a snap in coupling.

However, these hearing aid devices have substantially been designed for stimulating the inner ear on the same side of the skull where the apparatus is placed, and they have so far not been used for rehabilitation of those patients mentioned above, i e patients with single sided deafness.

It is an object of the present invention to provide a hea-

ring aid for rehabilitation of the patient category that has been described here, but which hearing aid in contrast to the above-mentioned so-called CROS and BICROS devices is based on the bone conducting principle, i e a bone anchored hearing aid in which the vibratory device is mechanically anchored in the skull bone by means of osseointegration.

According to the invention the bone conducting hearing aid is arranged to be installed outside or partially implanted in the skull bone at the deaf side of the patient with the vibratory generating part of the hearing aid mechanically anchored in the skull bone by means of osseointegration and arranged to transmit vibrations through the skull bone from the deaf side to the inner ear on the other side of the patient.

According to a preferred embodiment of the invention the frequency characteristic is specifically adapted to transmit vibrations in the skull bone from one side of the skull to the other.

In the following the invention will be described more in detail with reference to the accompanying drawings in which

figure 1 illustrates the principles for the hearing aid,

figure 2 illustrates an alternative embodiment of the invention in which the hearing aid is partially implanted, and

figure 3 illustrates an alternative solution with a partially implanted hearing aid in which the implantable part is arranged on the good (non deaf) side of the skull, while the external part of the hearing aid is placed on the deaf side.

Figure 1 shows schematically the skull of a patient with the auditory organs in the form of an external ear, auditory meatus, middle ear and inner ear. The patient has a profound hearing loss in the inner ear on one side but normal or only a slightly impaired hearing on the other side. On the deaf side there is a hearing aid anchored in the skull bone, preferably in the mastoid bone behind the external ear. The hearing aid comprises a housing with a vibrator 1 which via a skin penetrating spacer 11 is mechanically anchored in the skull bone 2 by means of a fixture 3. The sound is picked up by the hearing aid by means of a microphone 5 and is then amplified and filtered in an electronic circuitry 4.

As it is mainly the high frequencies which are attenuated at the bone conduction from one side of the skull to the other, the frequency characteristics of the hearing aid is preferably adapted for this application which means that the amplification is higher in the treble, frequencies above 1 kHz, than in the bass, which is in contrast then to an ordinary bone anchored hearing aid.

As the vibrations from the vibrator 1 in this case must be transmitted from one side of the skull to the other it is, due to specific resonance and attenuation characteristics in the skull, an advantage if the electronic circuitry 4 comprises means for converting the signal from the microphone 5 from an analog to a digital signal for the necessary signal processing. Such signal processing means can then be used for adapting for instance the frequency characteristics to individual differencies in the head shadow effect, the sound environment, the skull resonance, sound direction and the hearing capacity of the well-functioning ear. The signal processing means can also be used for actively counteracting acoustic feed-back problems.

In order to avoid skin penetration the hearing aid can be made with an implantable part including the vibrator and

an external part including the microphone 6, see figure 2. The external part 7 then also comprises a battery 9 and the power is transmitted to the implanted part 8 of the hearing aid by means of induction.

In figure 3 it is illustrated an alternative embodiment of the hearing aid in which the implanted part also comprises a rechargeable battery 10 which is charged by means of induction from an external power supply. In this case the implanted part 8 is arranged on the non-deaf side of the skull, while the external part 7 with the microphone 6 and the battery 9 also in this case are located on the deaf side of the skull. The transmission of the signal from the external part 7 to the implanted part 8 can be effectuated by means of an analog or a digital radio signal.

The invention is not limited to the examples described here but can be varied within the scope of the accompanying claims.

CLAIMS

1. A hearing aid apparatus of the type which is intended for sound transmission from one side of the head to the cochlea on the other side of the head for rehabilitation of patients with unilateral hearing loss, i e individuals with a normal or a slightly impaired hearing on one ear and a profound hearing loss in the inner ear on the other side of the head c h a r a c t e r i z e d i n that it is based on the bone conducting principle for bone anchored hearing aids and comprises a vibratory generating part which is mechanically anchored by means of osseointegration in the skull bone at the deaf side of the patient and arranged to transmit vibrations through the skull bone from the deaf side to the inner ear on the other side of the patient.

2. Hearing aid apparatus according to claim 1 c h a r a c t e r i z e d i n that the frequency characteristics of the apparatus is specifically adapted to transmit vibrations in the skull bone from one side of the skull to the other side.

3. Hearing aid apparatus according to claim 2 c h a r a c t e r i z e d i n that the frequency characteristics of the apparatus is adapted in such a way that the amplification is higher for frequencies above 1 kHz than for lower frequencies which is in contrast then to an ordinary bone anchored hearing aid.

4. Hearing aid apparatus according to claim 1 c h a r a c t e r i z e d i n that it comprises an electronic circuitry (4) in which the signal from the microphone (5) of the hearing aid to the vibrator (1) is converted from an analog to a digital signal.

5. Hearing aid apparatus according to claim 4 c h a r a c t e r i z e d i n that the electronic circuitry (4) com-

prises digital signal processing means, for instance for adapting the frequency characteristics to individual differencies in the acoustic head shadow effect, the sound environment, the skull resonance, the hearing capacity of the well-functioning ear, etc.

6. Hearing aid apparatus according to claim 4 c h a r a c t e r i z e d i n that the electronic circuitry (4) comprises signal processing means for actively counteracting acoustic feed-back problems in the apparatus.

7. Hearing aid apparatus according to claim 4 c h a r a c t e r i z e d i n that it comprises directivity means in the form of one or more directivity dependent microphones and/or signal processing means in the electronic circuitry (4).

8. Hearing aid apparatus according to claim 1 c h a r a c t e r i z e d i n that it comprises an implantable part (8) with a vibrator (1) arranged to be anchored in the skull bone (2) and an external part (7) provided with a microphone (6) and a battery (9), and that the power to the implantable part (8) is transmitted from the external part (7) by means of induction.

9. Hearing aid apparatus according to claim 8 c h a r a c t e r i z e d i n that the implantable part (8) comprises a rechargeable battery (10) arranged to be charged by means of induction from an external power supply.

10. Hearing aid apparatus according to claim 9 c h a r a c t e r i z e d i n that the signal transmission from the external part (7) to the implantable part (8) is effectuated by means of an analog or a digital radio signal so that the implantable part (8) can be placed on the same side of the skull as the hearing aid while the external part (7) is arranged on the deaf side of the skull.

Fig. 1

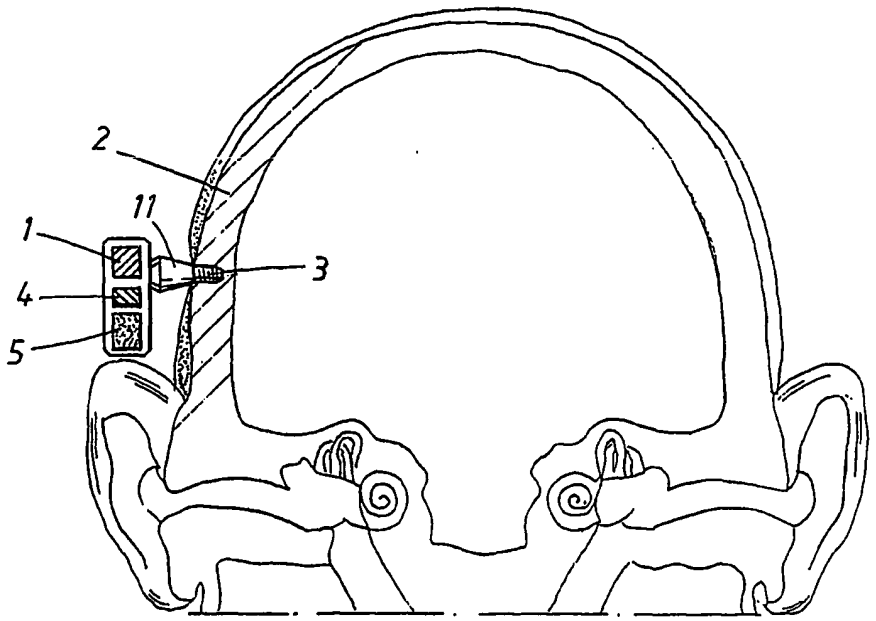


Fig. 2

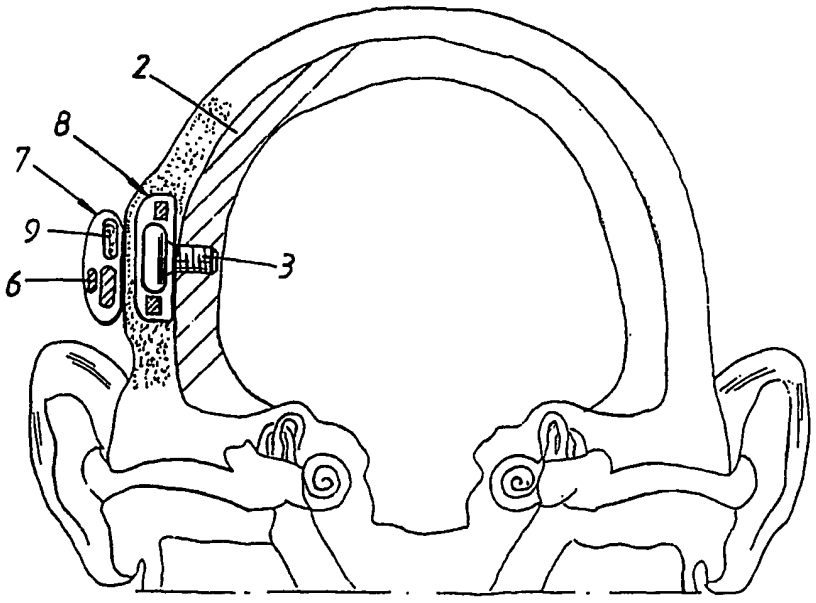
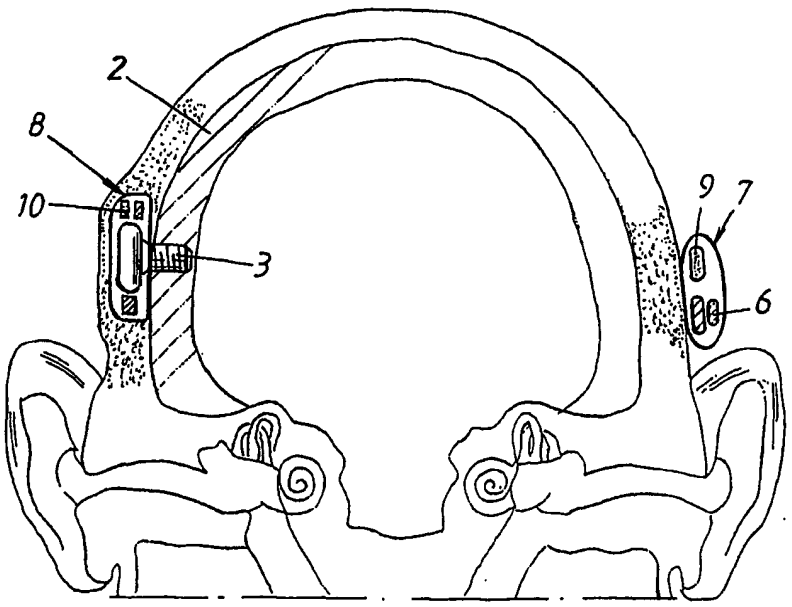


Fig. 3



INTERNATIONAL SEARCH REPORT

International application No.
PCT/SE 02/01089

A. CLASSIFICATION OF SUBJECT MATTER

IPC7: H04R 25/00
According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC7: A61F, H04R

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

SE,DK,FI,NO classes as above

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

EPO-INTERNAL, WPI DATA

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 3809829 A (W.R. VIGNINI ET AL), 7 May 1974 (07.05.74), column 1, line 5 - line 6; column 1, line 36 - line 38	1
A	US 5323468 A (H.W. BOTTESCH), 21 June 1994 (21.06.94), abstract (last sentence), figure 2	2-5
A	WO 9112783 A1 (TARI, R. ET AL), 5 Sept 1991 (05.09.91), abstract	2,3,8,9
A	US 5800475 A (F.M.G. JULES), 1 Sept 1998 (01.09.98), figure 2 and text	4-5,8-9

[X] Further documents are listed in the continuation of Box C. [X] See patent family annex.

* Special categories of cited documents:
"A" document defining the general state of the art which is not considered to be of particular relevance
"E" earlier application or patent but published on or after the international filing date
"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)
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Date of the actual completion of the international search	Date of mailing of the international search report
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INTERNATIONAL SEARCH REPORT

International application No.
PCT/SE 02/01089

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 5913815 A (G.R. BALL ET AL), 22 June 1999 (22.06.99), column 12, line 54 - line 56; column 20, line 28 - line 30 -- --------	8-9

INTERNATIONAL SEARCH REPORT

Information on patent family members

02/09/02

International application No.
PCT/SE 02/01089

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US 3809829 A	07/05/74	DE 2401962 A	25/07/74
US 5323468 A	21/06/94	NONE	
WO 9112783 A1	05/09/91	AU 7487891 A	18/09/91
		FR 2659009 A	06/09/91
US 5800475 A	01/09/98	AU 5453196 A	12/12/96
		EP 0745363 A	04/12/96
		FR 2734711 A,B	06/12/96
		JP 8322873 A	10/12/96
US 5913815 A	22/06/99	EP 0801878 A	22/10/97
		JP 11506572 T	08/06/99
		US 5800336 A	01/09/98
		US 5897486 A	27/04/99
		AU 4695996 A	24/07/96
		US 5624376 A	29/04/97
		US 5857958 A	12/01/99
		WO 9621335 A	11/07/96
		AU 683671 B	20/11/97
		AU 7179594 A	24/01/95
		CA 2165557 A	12/01/95
		EP 0732035 A	18/09/96
		JP 8512182 T	17/12/96
		US 5554096 A	10/09/96
		US 6190305 B	20/02/01
		US 2001003788 A	14/06/01
		WO 9501710 A	12/01/95
		US 5456654 A	10/10/95